A Real-Time Bi-Directional Differential GPS

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NASA ICNS Workshop

May 20-22, 2003

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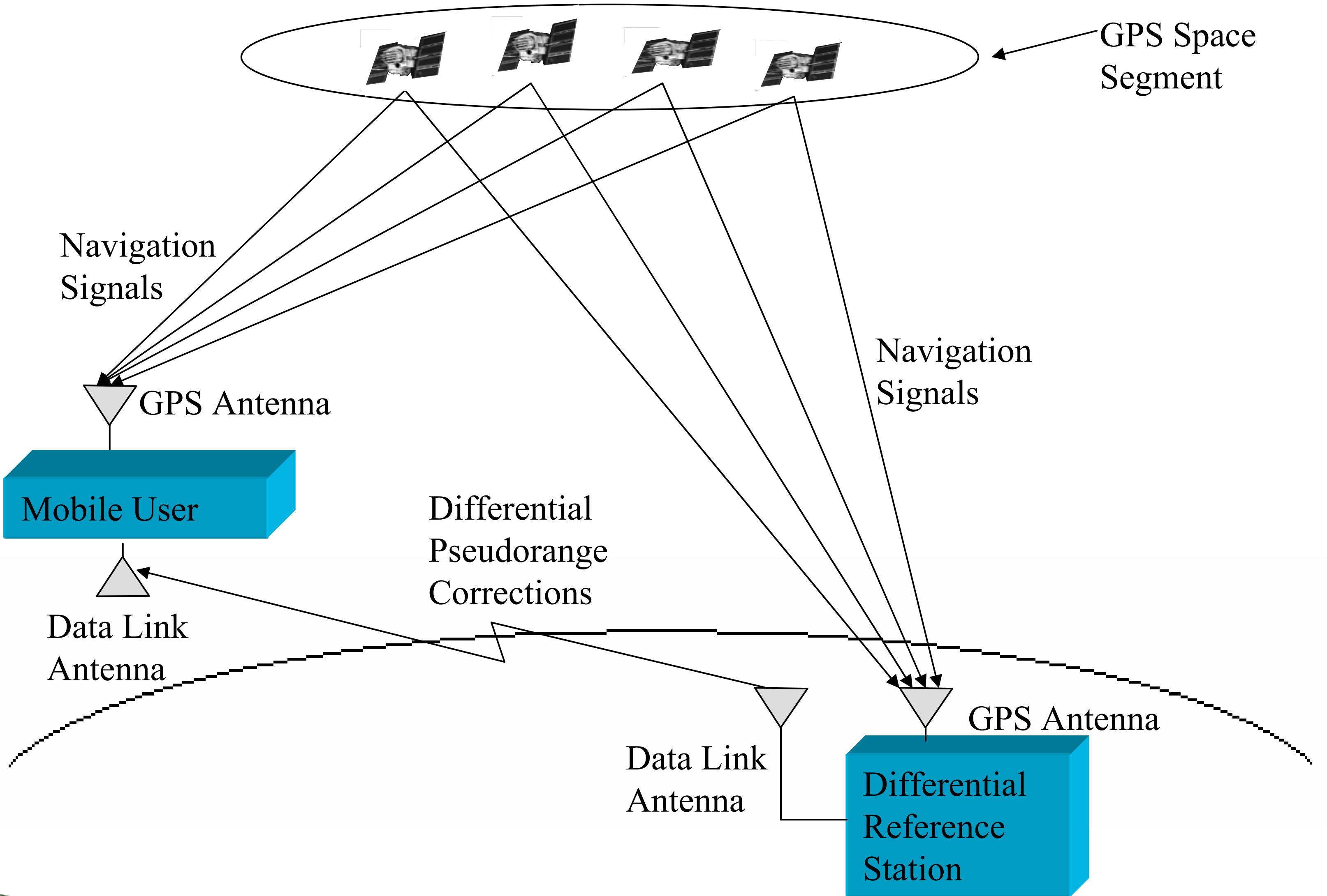
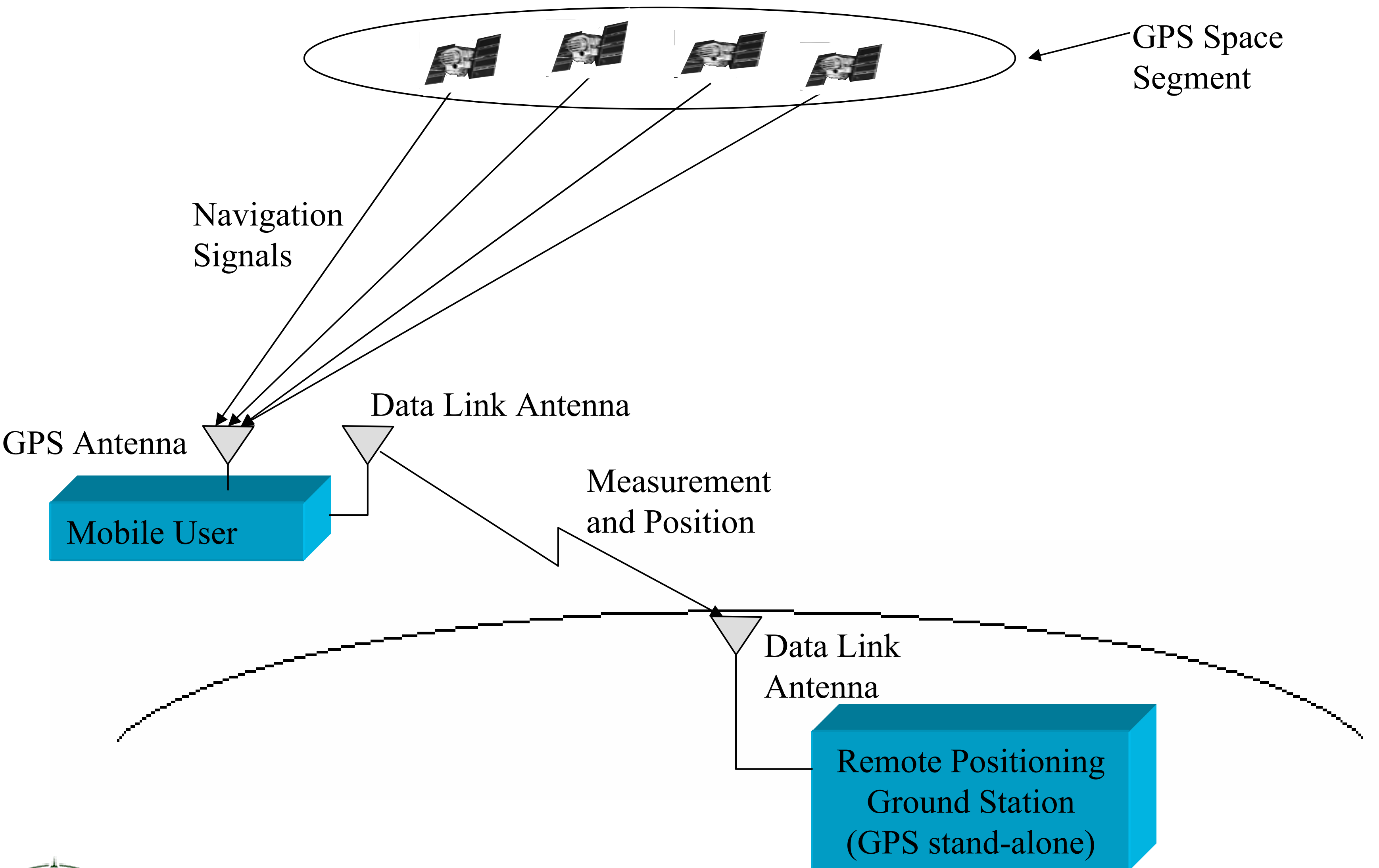
Outline

- Background
    - DGPS
    - Remote Positioning
- Bi-Directional DGPS
- Data Link Requirements
- Scope of Demonstration
- Prototype Architecture
- Result Analysis and Plots
- Summary and Conclusion
- Recommendations for Future Work

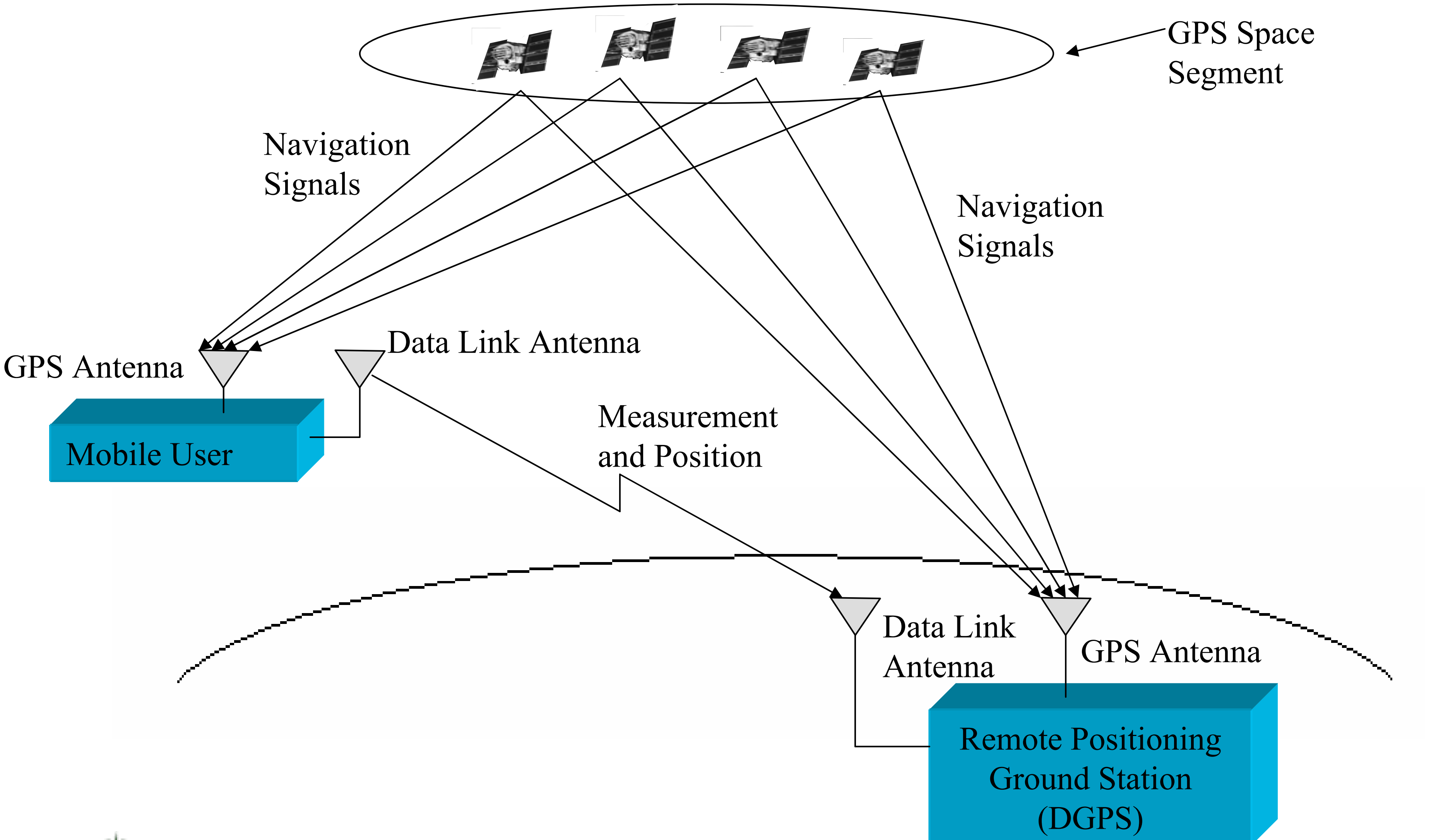
DGPS Illustration



Remote-Positioning (stand-alone) System



Remote-Positioning DGPS System



Positioning Requirements

Uplink

Differential Pseudorange Corrections

- Enables high accuracy position solution at the user end
- Enables added integrity, precision landing, auto pilot, closer spacing, etc.

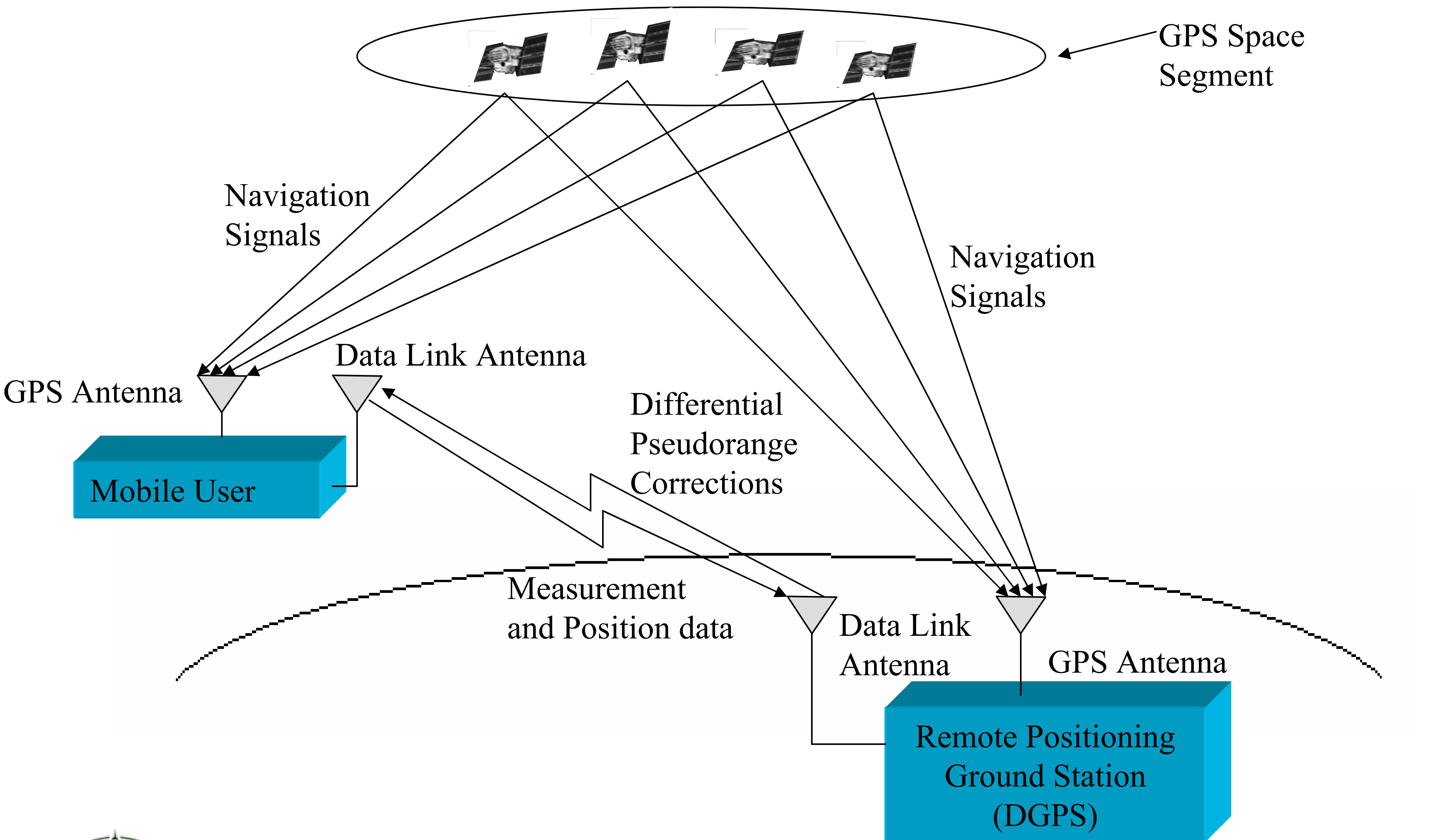
Downlink

Measurements and Position

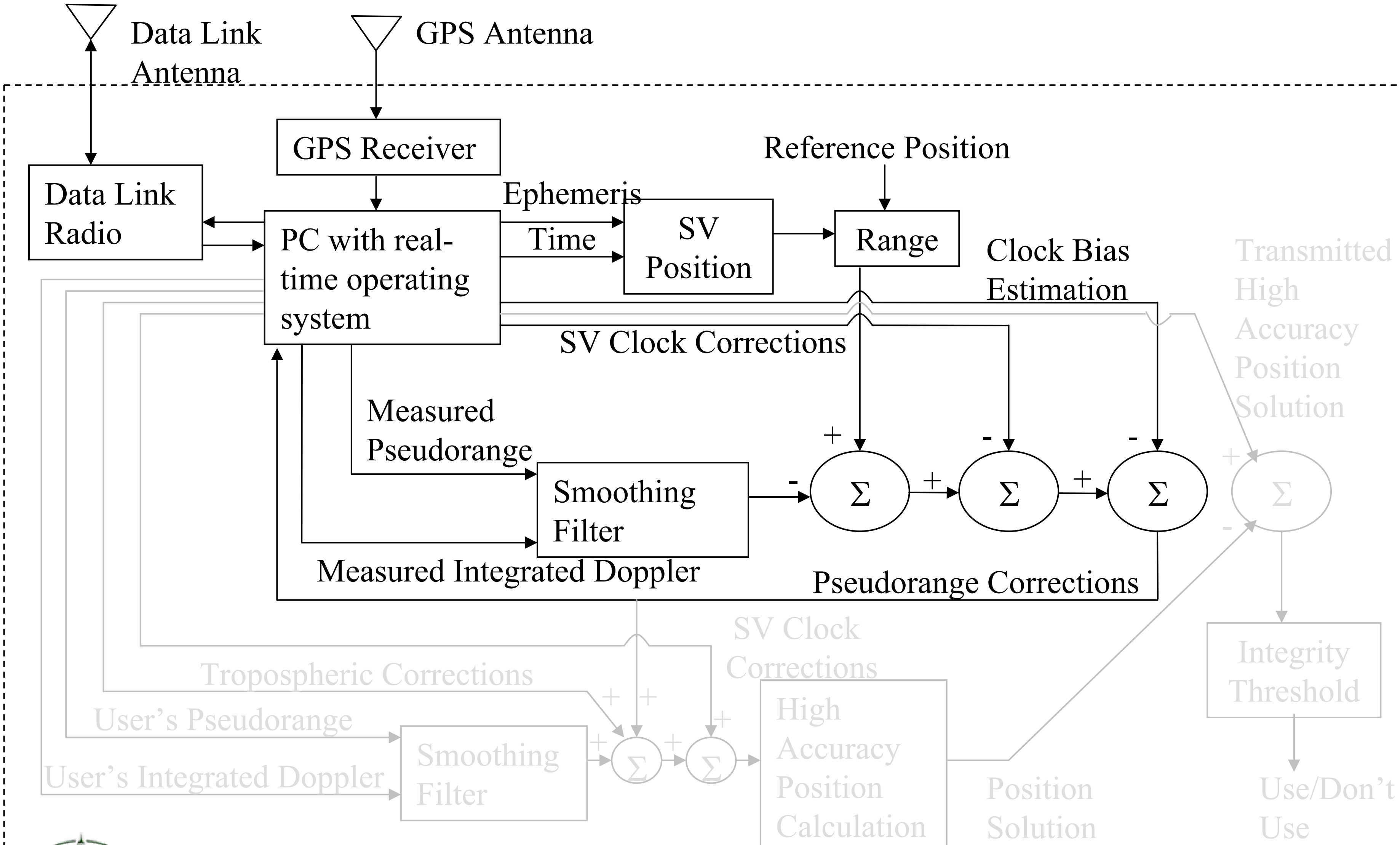
- Transmit observable measurements in addition to user PVT – future growth
- Enables high accuracy position solution of the remote user at the ground station
- Could be used for cooperative tracking system in the absence of a local air traffic control radar.
- Could control, track, and monitor an aircraft, a launch vehicle, or a UAV from a remote position

We want both – Simultaneously, within the same architecture

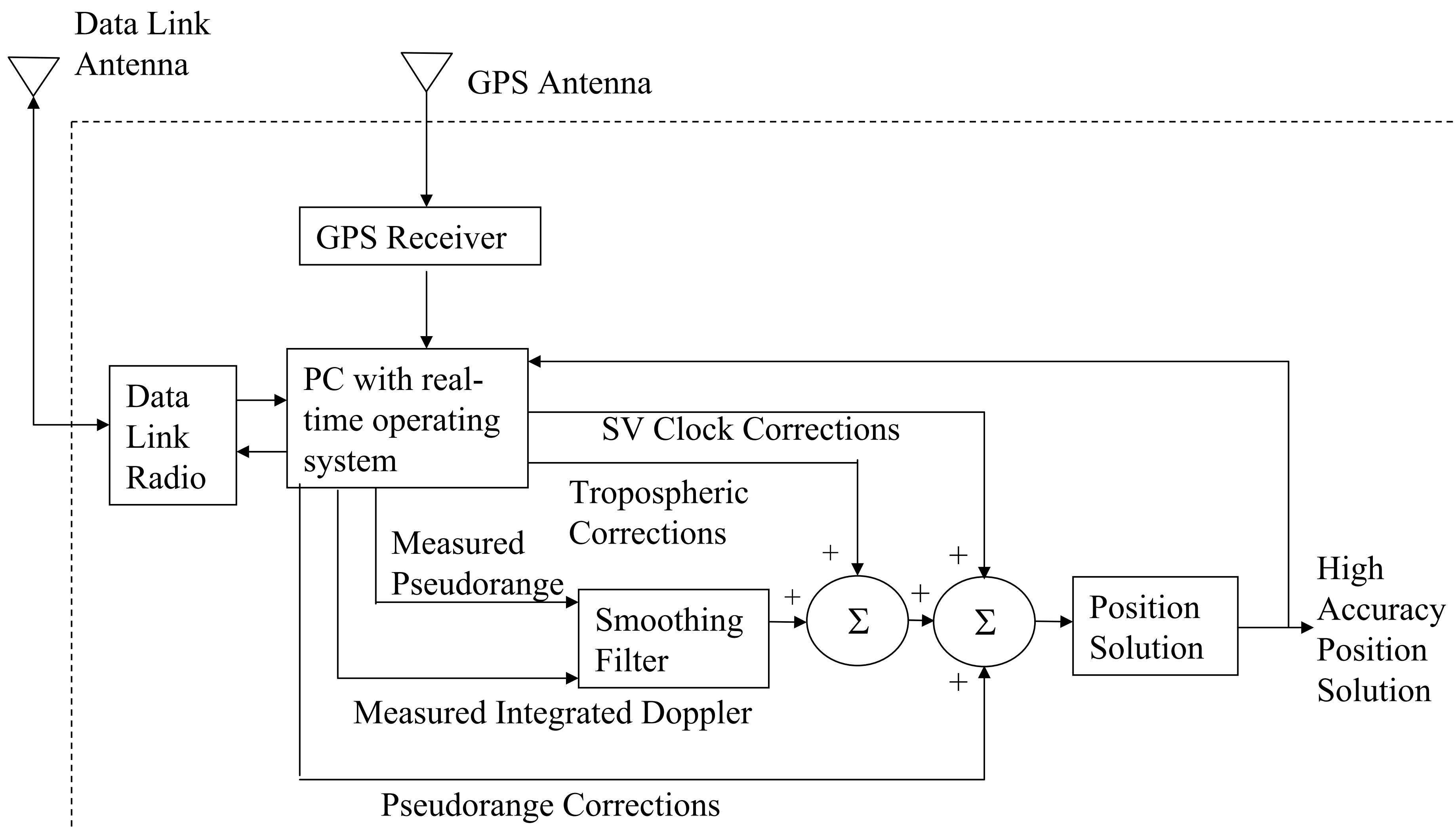
Bi-directional DGPS



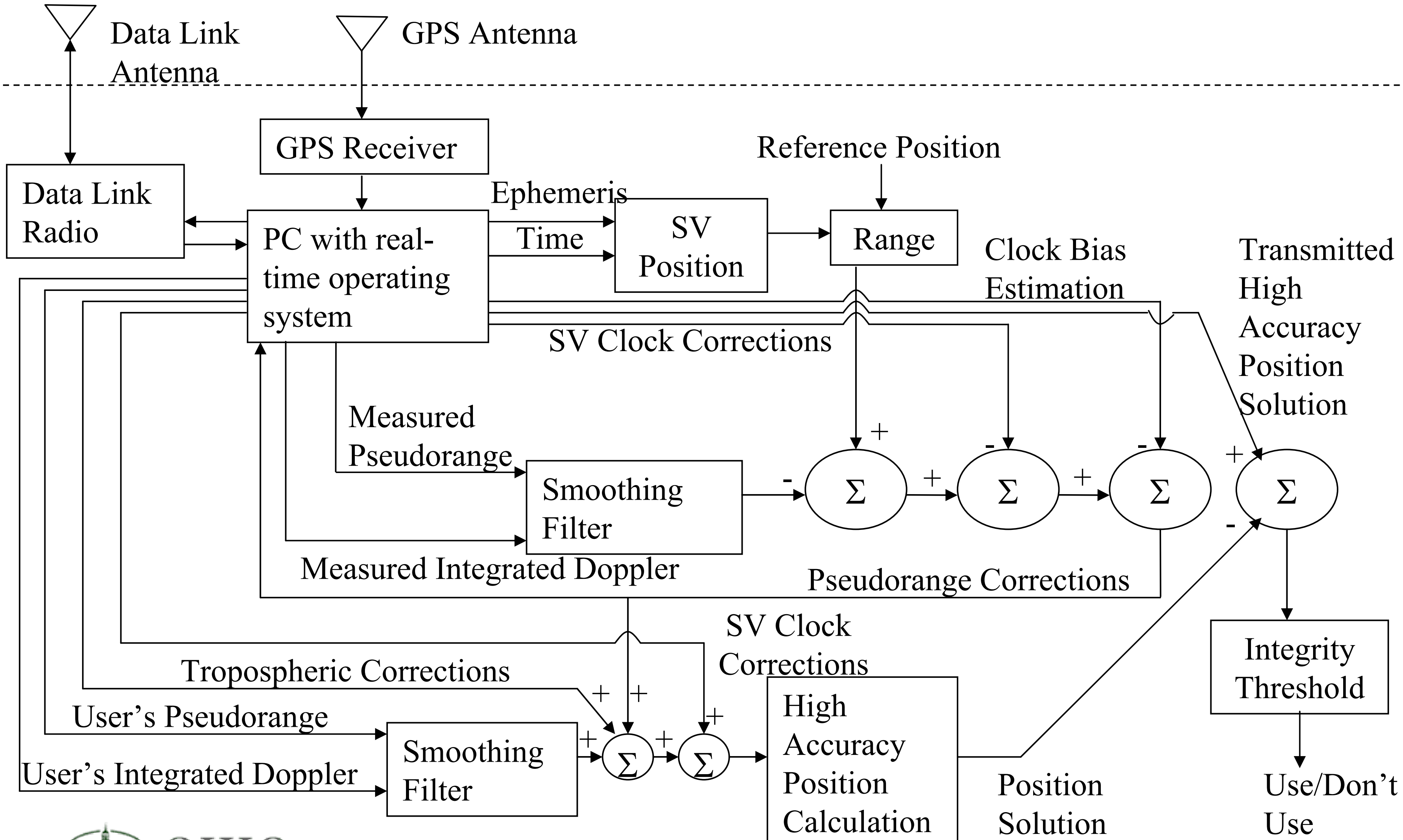
Bi-directional DGPS Ground Station (Up-Link)



Bi-directional DGPS Mobile User



Bi-directional DGPS Ground Station (Up & Down-Link)



Data Link Parameters

Uplink is analogous to LAAS Message Type 1

- 6 Header Bytes
- 222 Data Bytes
- 32-bit CRC for Integrity

<u>LAAS Message Block Header:</u>

Parameters	Number of Bytes
Synchronization byte (1)	1
Synchronization byte (2)	1
Message ID	1
Sequence Number	1
Bytes to follow	1
Checksum (End of the message)	1
Total	6

VDB Uplink (Uplink)

Prototype LAAS Data Parameters Uplinked:

Parameters	Format	Number of Bytes
GPS Time	Double	8
σ_{pr_gnd}	Integer	1
Data Checksum	Integer	4
SV Number (for up to 13 satellites)	Integer	1×13
Pseudorange Corrections (for up to 13 satellites)	Float	4×13
Integrated Doppler (for up to 13 satellites)	Float	4×13
B-Values from first RR (for up to 13 satellites)	Integer	1×13
B-Values from second RR (for up to 13 satellites)	Integer	1×13
B-Values from third RR (for up to 13 satellites)	Integer	1×13
B-Values from fourth RR (for up to 13 satellites)	Integer	1×13
Issue of Data or IOD (for up to 13 satellites)	Integer	1×13
Padding	Integer	27
Total		222

Data Link Parameters (Downlink)

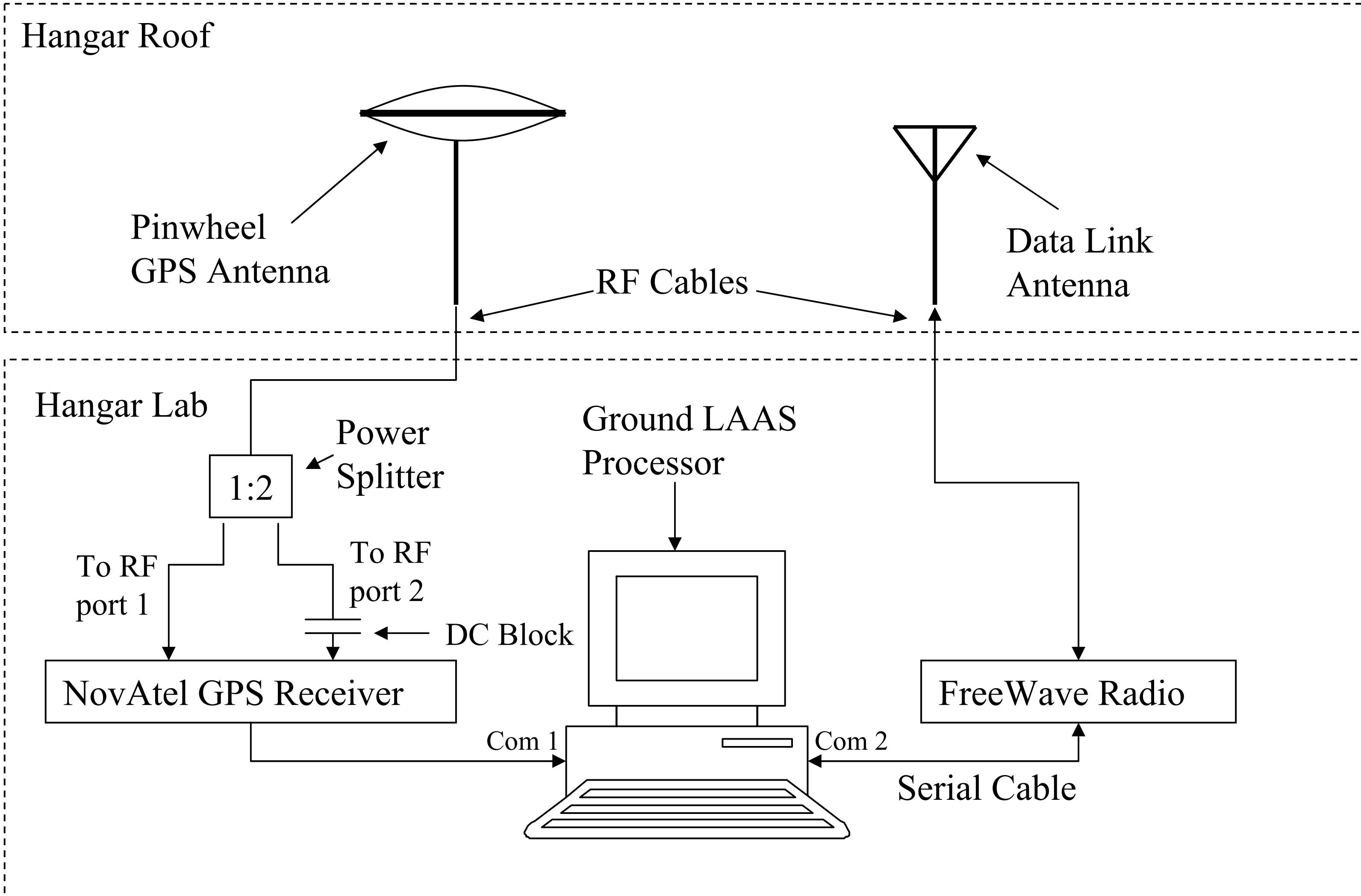
Prototype LAAS Data Parameters Downlinked:

Parameters	Format	Number of Bytes
GPS Time	Double	8
Data Checksum	Integer	4
Differentially corrected East Coordinate	Float	4
Differentially corrected North Coordinate	Float	4
Differentially corrected Up Coordinate	Float	4
Position Time	Double	8
SV Number (for up to 13 satellites)	Integer	1×13
Pseudorange (for up to 13 satellites)	Double	8×13
Integrated Doppler (for up to 13 satellites)	Float	4×13
Padding	Integer	27
Total		228

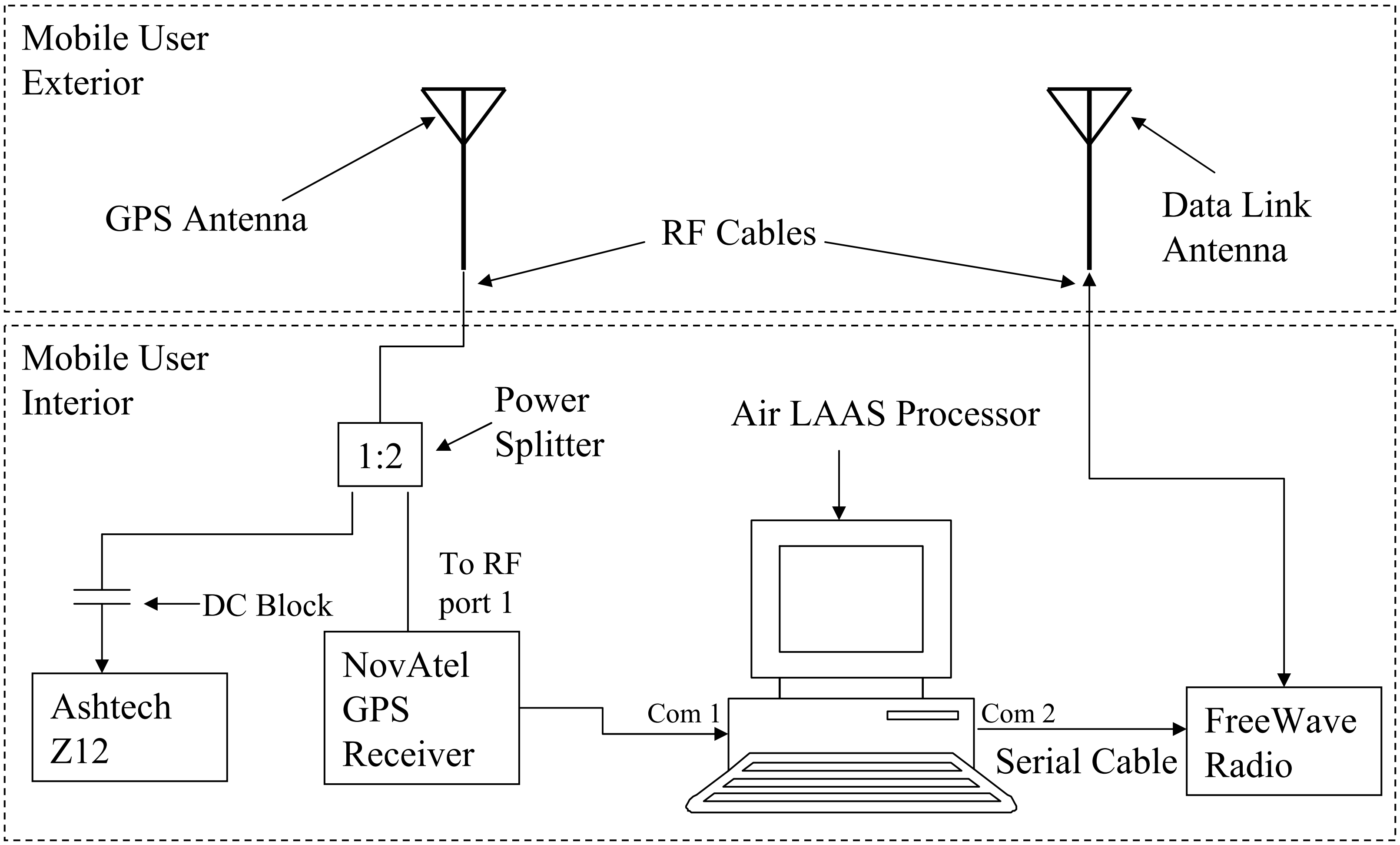
Scope of Demonstration

- Rather than a one-way LAAS VDB, a bi-directional Freewave Radio (@ 902 MHz) was used for Data Link
- Lab Test
  - Single GPS Feed
  - Different Ground and Air GPS Feed
- Van Test
  - Data Link Coverage for Surface Movement
- Flight Test
  - One day (9.4/02), 6 low approached then land using Ohio University DC-3 Aircraft at UNI

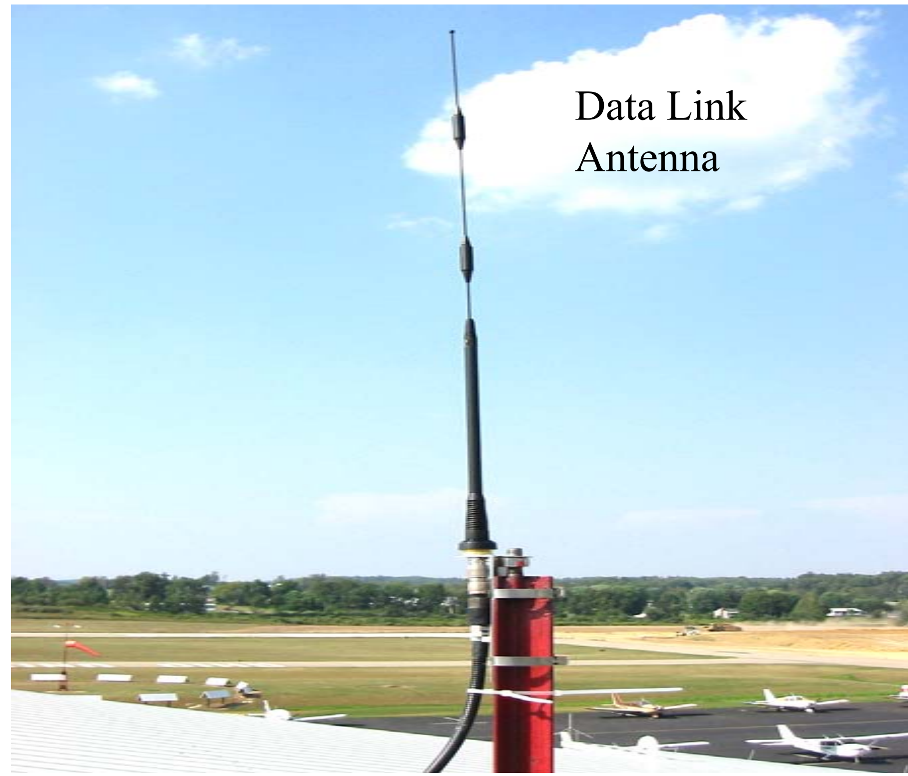
Prototype Architecture of the Ground Station



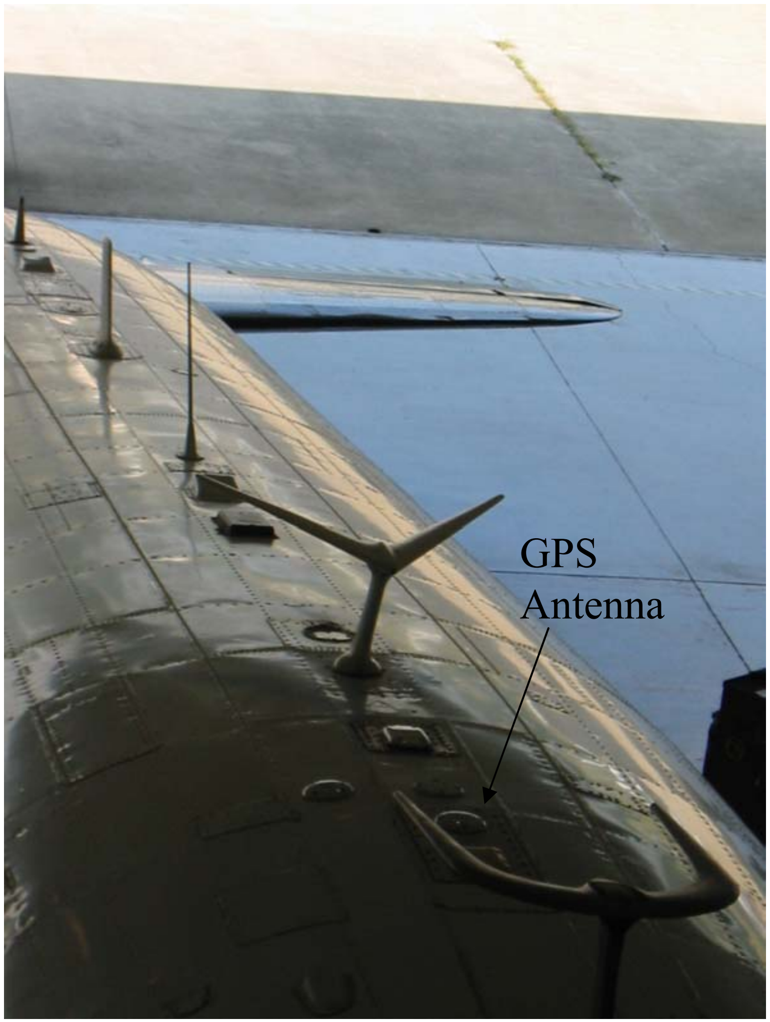
Prototype Architecture of the Mobile User



Ground Station Antennas



Mobile User Antennas



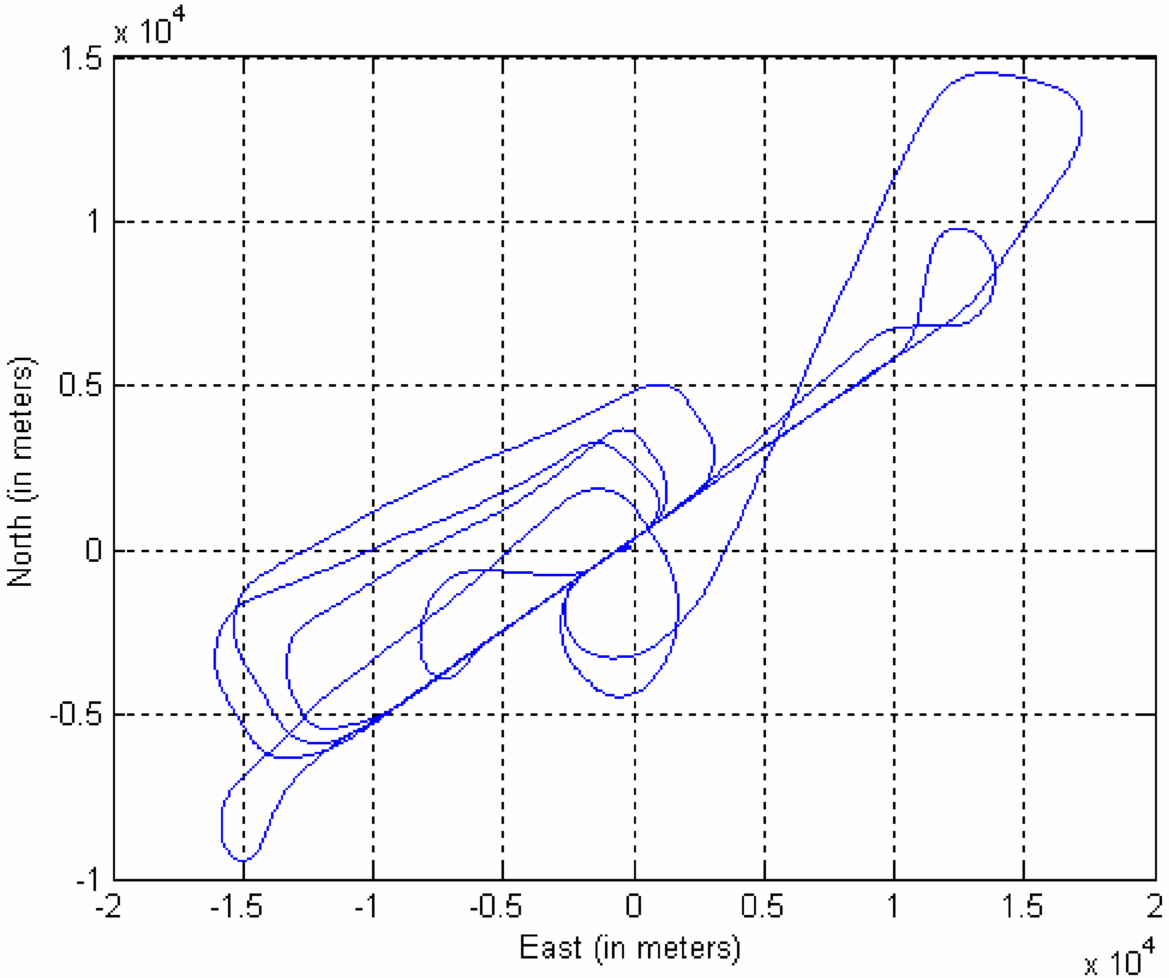
Aircraft Equipment Rack

FreeWave Data Link Radio

Ashtech Z12 GPS Receiver

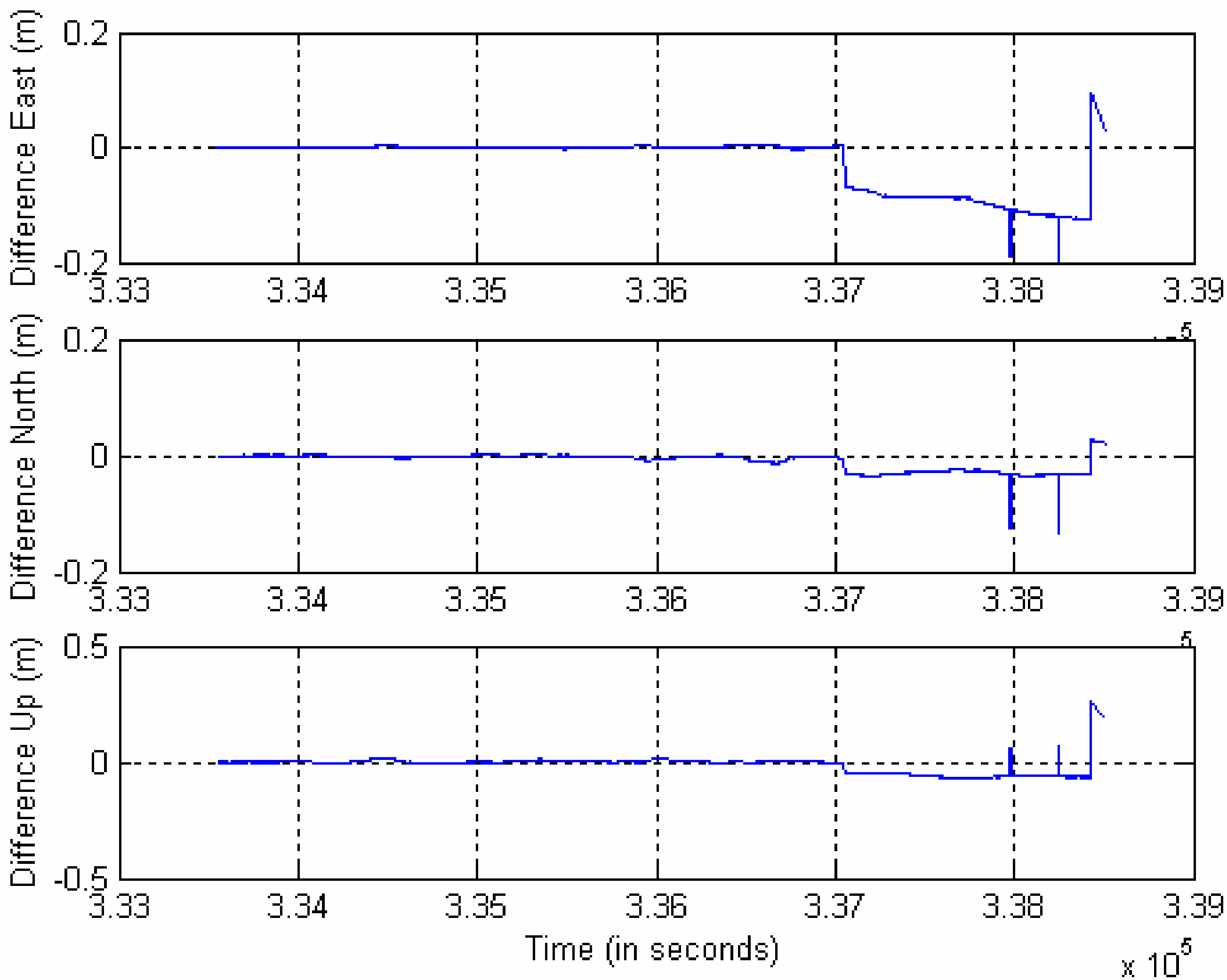
Prototype Bi-directional DGPS Airborne Processor

Aircraft Ground Track

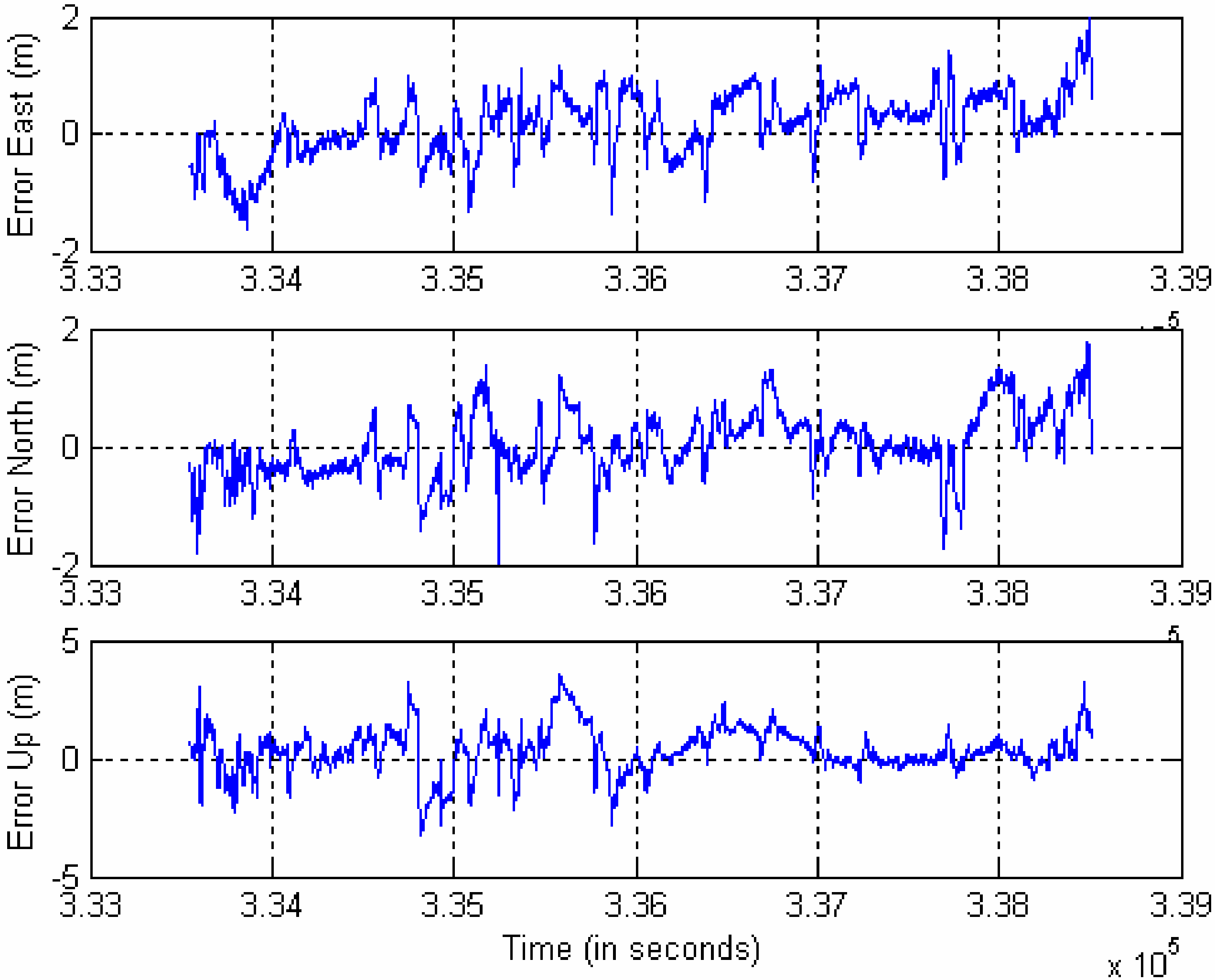


- (0,0) is DGPS Ground Station Location
- 0 to 1,800 ft altitude of flight path

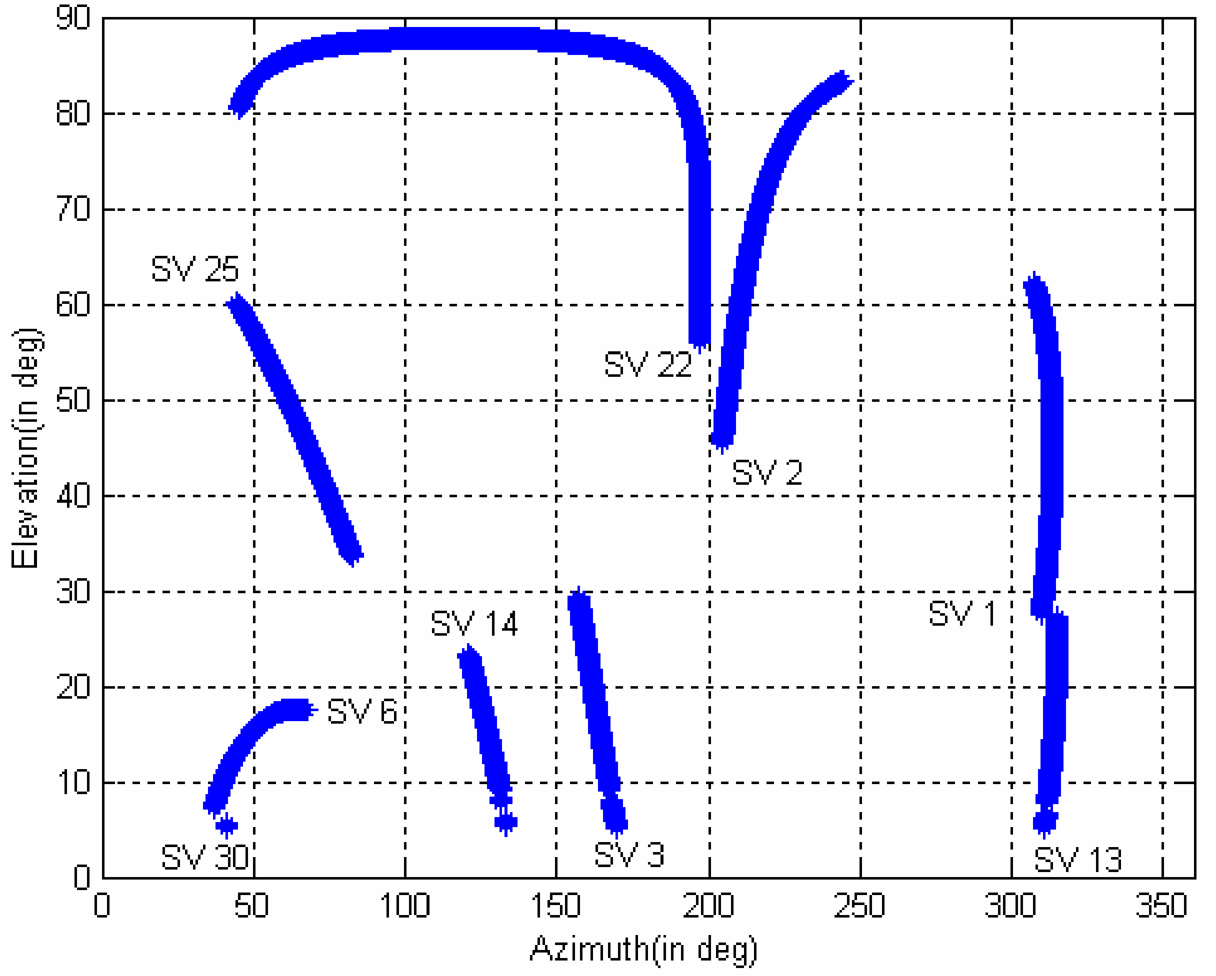
Difference in Aircraft Remote Positions



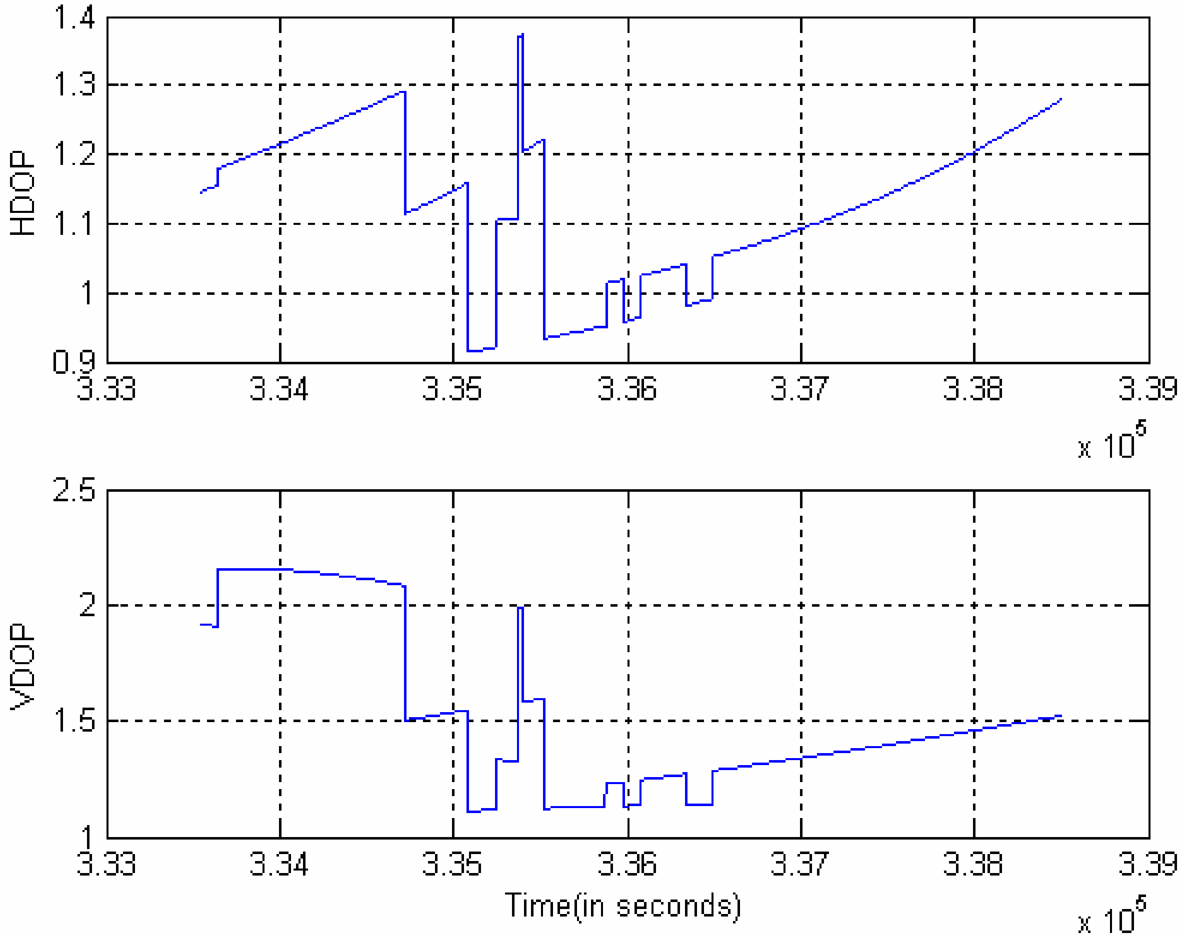
Absolute Error in Aircraft Remote Positions



GPS SV Sky Plot



Dilution of Precision



Result Analysis (1)

	Mean (m)	Standard Deviation (m)
Error in East Coordinates	0.161	0.549
Error in North Coordinates	0.026	0.548
Error in Up Coordinates	0.328	0.979
2drms (2-Dimensional)	1.552 m	
2drms (3-Dimensional)	2.499 m	

Result Analysis (2)

- Error in the East and North coordinates were relatively small
- Error in the Up coordinates were relatively higher for the following reasons:
  - Use of single GPS Pinwheel Antenna with moderate multipath mitigation technology
  - Positioning of the GPS Pinwheel Antenna on the hangar rooftop which was made of corrugated metal
  - Relatively high VDOP
- Other Possible sources of errors:
  - Typical B-values in the order of ±0.3 meters.
  - Ramp-like function observed in some of the SV PRC plots

Summary and Conclusions

- Bi-Directional DGPS was successfully demonstrated in real-time based upon a prototype LAAS architecture using a fixed ground station and both a van and an aircraft as a mobile user
- An integrity check was created for the remote position solutions of the aircraft transmitted to the ground station
- Very good agreement between mobile user and remotely calculated user positions
  - Essentially identical, except when ephemeris updates occurred.
- Error were reasonable low: very low in East and North with moderate errors in the Up coordinate (some DGPS reference station multipath)

Recommendations for Future Work

- Could be demonstrated in a fully populated LAAS and bi-directional data link
- Integrity monitor can be improved by setting a difference threshold and send warning to user
- The mobile user can transmit user PVT basis (i.e., stand-alone, WAAS, NDGPS, GPS/INS, etc.,) to the ground station in the absence of DGPS positions
- Velocity information can be downlinked to enable Instantaneous Impact Point (IIP) calculations with added integrity
- IIP calculations can be implemented in the ground station
- Implement additional ephemeris checking

A Real-Time Bi-Directional Differential GPS (QUESTIONS)

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Additional Information

Aircraft Remote Positions